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Abstract:

Recently, RFID has emerged to be a promising technology to revolutionize the supply chain and logistics management. Currently there exists a sharp contrast between retailers in China and their counterparts in the United States with respect for RFID adoption. In the United States, big retailers like Wal-Mart are actively pursuing RFID by issuing mandates to their suppliers worldwide for RFID adoption. However, retailers in China never enjoy such a dominating role in pursuing RFID. To explore what is behind this phenomenon, in this paper, an analysis framework is proposed to develop decision support tools for RFID technology adoption analysis in retailers in China. The framework is realized in a service platform developed based on three principles to help reach mutual understanding between RFID vendors and customers in RFID technology adoption analysis. The framework is illustrated and validated through an example to demonstrate its feasibility to help to analyze the adoption of RFID technologies retailers in China. The technology analysis service platform integrates various tools enabling interactive and flexible analysis processes to understand how RFID technology can be adopted and used effectively in retailers in China and in logistics and supply chain management.

Keywords: RFID, technology adoption, service platform, system implementation

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I. INTRODUCTION

Radio Frequency Identification (RFID) [Das 2002] is a wireless identification and tracking technology that allows a reader to activate a transponder on a radio frequency tag attached to, or embedded in, an item, allowing the reader to remotely read and/or write data to the RFID tag. Industry and public interest in RFID technology took a major leap forward in June 2003 when Wal-Mart mandated its largest 100 suppliers to use RFID tags on shipped items at the pallet level by January 2005 [Bansal 2003]. Recently, RFID has emerged to be a promising technology to revolutionize the supply chain and logistics management, along with the unprecedented explosion in wireless networking technologies. These technologies are expected to co-exist to form a wireless environment enabling modern logistics and supply chain management. These new wireless paradigms will further pave the way for innovative services and applications in logistics and supply chain applications. In the meantime, it is certainly necessary to conduct technology evaluation in adopting these technologies while developing business opportunities. Thus, there is a demand for decision support tools for technology adoption in supply chain and logistics management to filter, pick, and deploy the technologies that can drive business value.

In China, RFID technology is becoming mature and used in logistics industry. In 1996, Foshan city installed a RFID system [Chen 2003] to automatically charge the vehicles going through the roads and bridges to improve the throughput of the road and the transportation efficiency. Railway Car Number Automatic Identification System (ATIS) was successfully piloted by China Railway in 2001. It was reported in [China Information World 2005] that ATIS can save 300 million RMB annually. Shanghai EMS attached RFID tags on their packages to automatically process the post packages [Li, Wei, and Wang 2006]. The RFID-based system was put into use in December 2005.

China manufacturers started to follow recent global RFID adoption trend partly because global buyers require their suppliers in China to put RFID tags on their products for global supply chain visibility and efficiency. Haier delivered a manufacturing procedure control system based on RFID, which helps Haier improve its process efficiency and product quality. In April 2005, State Tobacco Monopoly Administration [He 2005] decided to use RFID tag in tobacco industry, and Hangzhou Cigarette Factory became the first successful case of RFID application in tobacco industry. A novel type of retail service based on RFID technologies for aviation was developed [Li and Dong 2006]. In [Zhang et al. 2006], a low-power consumption RFID system was successfully applied at Macau Custom.

This has become a strong demonstration for China to leverage advanced technologies in order to maintain the country's competitive advantage in global economy. It also give a good push for China to adopt RFID technology to improve its logistic and supply chain management infrastructure to enhance and optimize the performance of China's logistics industry. Retailer, a key component in logistics, needs to deploy RFID technology to achieve and benefit from this total supply chain visibility and efficiency. However, retail business nature, e.g. sourcing goods from different suppliers, makes it very likely that multiple RFID solutions would be housed under the same roof. This makes the RFID adoption decisions in retailers to consider not only single RFID solution but also effective integration technologies that facilitate deployment of multiple RFID solutions under the same environment.

While retail companies like Wal-Mart in the United States have been actively pursuing RFID by issuing mandates to its suppliers, retailers in China rarely enjoy as comparable position as their U.S. counterparts do. This sharp contrast to what is happening in U.S. and other developed countries where RFID activities are mainly led by big retailers (e.g. Wal-Mart) interests and intrigues us. Geographically positioned in Hong Kong, a part of China, we are particularly interested in exploring what is behind this phenomenon.

Therefore, this paper is dedicated to present a situation analysis of retailers in China to attain an in-depth understanding of the adoption status. We will perform the following study to further understand what retailers care about and explore how we can help. The rest of the paper is organized as follows:

- Section II: Motivation - what leads to this study
- Section III: Our approach – an analysis framework to help China retailers in RFID adoption
- Section IV: System realization of this analysis framework to provide tools in technology analysis
- Section V: An illustration of our approach through an example
- Section VI: Approach assessment to evaluate our approach
- Section VII: Conclusion of this paper

II. WHAT LEADS TO THIS STUDY?

What can Can RFID Promise for Retailers?

A recent study in our project [Tan. and Ni 2007] helps identify the potential RFID promises for retailers. For example, RFID can potentially be used by retailers to automate and improve backroom management, shipping in/out processes, shelf management and stocking processes, point-of-sales, etc. All of this can lead to the following benefits for retailers adopting RFID technologies in their various business processes:

Advanced Shipping Notices (ASN)

RFID is able to automatically detect when either a pallet or shipment has left a retail store toward its clients. It will allow not only generation of an electronic ASN and recipient notification, but also billing of clients in real time instead of waiting until the end of the week or month, and doing a batch operation [Motorola Symbol 2004, USDOD RFID 2008].

Shrinkage

One of the major problems in the retail stores is product loss or shrinkage, which can account for anything from 2 to 5 percent of stock. The causes may vary from misplaced orders, employee and customer theft or inefficient stock or shelf management. RFID, with its superior tracking and identification capability, will be able to localize where losses are occurring [Motorola Symbol 2004, USDOD RFID 2008].

Returned Goods

RFID could deliver full asset visibility, process automation, and track-and-trace, which can be potentially achieved on returned goods to the retail stores thereby reducing fraud in reverse logistics [Motorola Symbol 2004, USDOD RFID 2008].

Anti-Counterfeiting

Illegal duplication and manufacturing of high-value products, are one of the industries' most well-known problems. By integrating a tag into items, for example, the body of an expensive ladies' handbag, RFID has the potential to authenticate a product, thus building customer confidence and loyalty in the retail stores [Juels 2006].

Improved Stock/Shelf Management

Managing stock and shelf is the key priority for many retailers [Motorola Symbol 2004, USDOD RFID 2008]. Studies have shown that on average, products are not on the store shelves 7 percent of the time due to inefficiencies in stock management, which means of course potential purchase loss. Implementing RFID at the item level and on shelves will give an automatic way of knowing and managing stock levels. However in order to achieve this on a large scale, it is recognized that tags will have to come down in price to around five cents or less, and readers to around 100 USD [Kearny 2003].

Situations of Retailers in China

The previously mentioned potentials are a rather visible, however a little superficial, lack of linkage to retailers' actual business processes and operating environment. So far, the world's leading retail giants like Wal-Mart and Carrefour have entered China. Wal-Mart and IBM have established their sourcing center in China as well. Thus, their suppliers are forced to deploy RFID in order to meet the mandate, e.g. from Wal-Mart. Compared with these resourceful counterparts, the local China retail companies (e.g. in Pearl River Delta—PRD) are rather small and medium but quite skillful in operating branded chain stores and specialty stores [HKTDC 2005]. Thus, Hong Kong Trade Development Council (HKTDC) calls for right entering strategies to exert strength for Hong Kong companies when entering PRD retail market. Up until 2004, local China retail stores still dominated consumer market in China [Lau 2004]. However, without the mandate pressure for adopting RFID like big suppliers for Wal-Mart, retailers in China have to face the following situations if they choose to try RFID to improve their business operations.

Potential Multiple RFID Standards Exist

As China is the source of a myriad of manufactured goods, it is expected that China adopt RFID standards compatible and interoperable with the world which is dominated by EPCGlobal's Electronic Product Code (EPC) proposals. Internally, China retailers also have to tackle the heterogeneity problem of their potential RFID solutions. Chinese government has expressed interest that it would propose its own RFID standard, by forming many technical committees (TC) focusing on specific technologies and business areas [Weng 2004]. China is also in the process of studying and evaluating international standards ISO 18000-1,2,3,4,6,7. There may be extensions to those ISO standards in a Chinese version covering special needs for China [Hao 2007].

RFID Technology Readiness

In China, RFID is at the stage to catch up with their counterparts in developed countries for developing RFID technologies. A few years ago, China did not even have RFID packaging capabilities which is the base for manufacturing RFID tags. RFID companies in developed countries may possess needed technology, but their entry into the China market needs time and preparation to get familiar with Chinese business culture, if they choose to do so [HKTDC 2005].

Although the RFID technology is constantly improving, there are still limitations related to the signal propagation and interference. This could pose severe problems for retailers where dense deployment of RFID is often needed. In retail, there are many open-loop applications which demand good security for RFID solutions. The features of the RFID systems and the constraints of RFID devices may bring about various security or privacy problems.

Further, successful RFID deployment requires integration of a large portfolio of ready technologies in different fields, including cryptology, information theory, radio frequency technology, antenna technology, computer science, microelectronics, electromagnetic compatible technology, etc.

Labor Cost versus Process Automation

RFID helps automate business processes, improve business efficiencies, which at the same time, would lead to reduction of labor. This seems very attractive to retailers in developed countries. However, labor cost in China is relatively cheaper, although on the growing trend. For example, the Shenzhen government, one of the most well-developed regions in China, recently released a report demanding companies in this city raise the basic monthly salary to 1000RMB [Shenzhen 2008], which is less than US$200.

IT Infrastructure Readiness

IT infrastructure in many Chinese retailers is not very advanced. Some of them even are not equipped with bar code systems. Operations in some small Chinese retailers are all manual. Recently, retailers in China started to invest in IT, mainly in the area of e-commerce and ERP [Chakravarti 2007].

Cost of RFID Implementation

Building and deploying RFID applications has been expensive. It requires a combination of customized development and knitting together with existing infrastructure software. Cost of the tags is still quite high. The tag cost can be significant for small to medium-sized manufacturers if shipping in large volume [Information Week 2007]. Although the tag price is said to be dropped to 12.9 cents (Alien Technology [O'Connor 2007]), it is not small enough for those low-profit product manufacturers and retailers in China to join this RFID business. And an RFID label printer costs about $4,000, a little more than twice the price of standard bar-code printers.

Value Chain Formation for RFID Adoption

A retailer has to cope with its upstream supply chain players in respect to the RFID adoption, like better inventory control, labor cost reduction, and order fulfillment rate increase, etc. The advantages of adopting RFID in retailers are quite visible in other parts of the world, since there are already a few successful pilot cases in the United States and many other western countries [Kilcourse 2006]. But it remains far from flourishing in China because there are few cost-effective models in retailers as benchmarks to follow.

Outsourcing Environment

Moreover, companies in China cannot always outsource RFID technology and services from third-party logistics providers (3PLs) to lower implementation cost as its counterparts (e.g. European Union and United States) do. In China, only 21 percent of large corporations (including multinational corporations) outsource logistics to 3PLs [RFID Journal 2007]. In the European Union and the United States, approximately 45 percent of corporations do so [RFID Journal 2007]. 3PLs in China are not capable yet to meet tremendous outsourcing demand yet. 3PL themselves are reluctant to take the potential financial risk of RFID adoption.

Are Retailers in China Interested in RFID?

Besides all the above, retailers in China, especially in PRD, face another big challenge. Many of these PRD retail and related companies are small- and medium-sized (SME) companies. Although they have acquired industry knowledge about their business, it often focuses on a very specific domain. Thus, even though many of them like to apply high tech, they often do not have enough business skills to conduct extensive technology adoption analysis. Thus, a good way to solve this problem is for them to source these kind of analysis skills with help from IT tools for conducting the analysis activities. However, in the meantime, among these companies, the very low level of IT capability of these SME logistics companies and expensive Total Cost of Ownership (TCO) of IT systems make the IT systems unaffordable to them.

Thus, it is not surprising to find that RFID adoption in retailers in China could be quite different from retail companies in the United States. However, our extensive engagement with companies in Hong Kong and Pearl River Delta (PRD) in China shows that retailers in China started getting interested in RFID technology. In PRD, there are about 80,000 manufacturing companies with Hong Kong connections [HKTDC 2008]. Hong Kong serves either as the window to the outside or as the retail store location. Further, Chinese people often go shopping relying on public transportation or on foot. Thus, retailing stores have to be located in easily accessible sites. Therefore, a much denser retailing network is often required, compared with their U.S. counterparts. We can see a closer interplay between good retailing with enough people passing by, easily accessible public transportation systems, and nice goods or logistics transportation in China. Accordingly, we have observed that the supply chain visibility and operation efficiency promised by RFID have gained interest in those companies in PRD. This type of relatively closer supply chain coupling among these companies yields potential demand for RFID technology in this region. The following is a summary of such demand:

- Many retail companies in this region source goods from different vendors. Potentially, the goods may be tagged with different RFID tags. Thus, it requires different RFID implementations in the company. Interoperability features needed to enable inter-exchange of RFID data and asset tracking.
- Some companies demand RFID technology to enhance their operation software to improve operation efficiency and asset track-and-trace management. They have also expressed interest in technologies to provide the interconnections to their partners' systems.
- A few companies are looking for software systems for asset management. Currently the way to manage the asset record is quite manual in many of these companies. Even though the extensive manpower has been used, which is still relatively cheaper in China, the data quality is still not up to standard. Thus, RFID becomes a potential technology.
- Some retail companies have seen the increasing need to provide better supply chain visibility and information integration with different logistics partners in PRD and worldwide. In order to provide timely information to its customers through a logistic information management system, RFID is viewed as a potential candidate for real time data capturing.
- Many retail companies in Hong Kong have goods transported across the border between China and Hong Kong which have to be tracked closely. Their current practice uses the existing barcode technology. While RFID is in the consideration; however, the discrepancy in the coding schemes in different regions like China, Hong Kong, and ultimate destination where the goods has to be tracked, causes problems for adoption.
- Some manufacturing companies have set up online retail stores. They wish to extend its online retail business platform with enhanced logistics software function to meet the requirements from its users and customers and increase the supply chain visibility and convenience for export business in and out of China.
- Some companies would like to address their operation wastage problem. They expressed interest, through RFID adoption, to demonstrate a good practice to other retail and logistics industry in China.

Do We Have a Role?

It can be seen that the expectation from RFID of those retailers in China is centering around improvement in internal operation efficiency (asset tracking, wastage reduction, real time data capturing for data quality) and partner and business interconnections (such as supply chain visibility, information interoperability). Recently, a retail project [Retail Project 2007] was awarded by the Hong Kong government to develop RFID-enabling technologies for retail and logistics industry. This industry-driven project targets to effectively promote the wide adoption of RFID technologies in retail and logistics industry in both Hong Kong and Pearl River Delta (PRD) region in China [Retail Project 2007]. It would provision: 1) a software platform to facilitate deployment of RFID application with multiple RF technologies in single premise; 2) retail and logistics application prototypes, such as backroom management, smart shelf, point-of-sales for easy adoption; and 3) multiple RFID applications showcases through pilot implementation [Retail Project 2007].

From this retail project [Retail Project 2007], we can see retailers in China are interested in how RFID can help their operations in backroom management, smart shelf, point-of-sales. In light of the differences between China and other developed countries, adoption strategy seemingly could be quite different for retailers in these different regions. While RFID solutions and applications are still at the early stage of deployment in China (e.g. shown in [Tan. and Ni 2007]), the potential for RFID to improve supply chain and logistics operational efficiency is evident, as demonstrated in a few pilots in retailers in the U.S. and Europe [Kilcourse 2006]. So far, although there are a few reports on RFID adoption analysis (e.g. [Curtin, Kauffman, and Riggins 2007]), we have not come across any research activities dedicated to RFID adoption in retailers in this regions (i.e. PRD, China).

Geographically stationed in Hong Kong, we are particularly interested in finding out how we can help retailers in China to sustain their growth potential developed in the last 30 years leveraging this promising technology RFID. Thus, we would like to explore what kind of role to play in helping them to fill in this gap. Toward this, we conducted extensive information exchange with business and technical colleagues engaging in RFID business in China and Hong Kong. They have expressed interest in a decision support tool for RFID adoption analysis to help their business engagement:

- These business engagement colleagues often go out to identify potential customers. Their feedback shows that in order for those retail companies to get interested in RFID, they have to see value in it. The value is often expressed as how it is relevant to their existing business operations.
- The business engagement colleagues have also asked if there is a tool available to help them to form a good strategy to identify the pain points in potential customers. Then value could be demonstrated to potential customers if RFID-related technology can address these pain points.
- The technical colleagues develop RFID technologies and solutions, leading to products available in the market. So far, features about RFID technology, solutions, and products are well described. However, these features are not yet easy to comprehend by potential customers who are not IT savvy.
- This leads to a situation where business engagement colleagues, when approaching potential customers, often only have the project experiences to sell. As potential customers often demand tailor-made, customizable solutions, mismatch between the selling content (project experiences) and what is expected (tailor-made and customizable solutions) from the customers arises.
- Partly what is behind this situation is that there is lack of well-established RFID business strategies to persuade and sell RFID and related solutions. There needs to be a framework to help them to sell the value of RFID and related solutions which can catch the interest of our potential customers.

Thus, we will take this challenge to develop such a framework that can be used by the engagement teams, and hopefully by others such as potential customers, to bridge the potential of RFID and things valued by potential customers in retail industry. In the following, we will present this framework to develop a flexible and interactive tool as the linkage between RFID vendors and RFID customers, leading to a mutual understanding of what can be supplied and what is demanded.

III. THE ANAYSIS FRAMEWORK

As the business engagement team has to sell the value of RFID and match up with what is valued by potential customers. Value becomes a central word in developing such a framework, which we call *value analysis framework*. Actually this is quite natural, coming down to the fundamentals such as demand and supply relationship analysis. As market participants exchange goods/services in the market, they are seeking what they need. In this classical demand and supply relationship, the value of the goods or services is often expressed as financial dollars or rewards in many forms.

In technology adoption, value is expressed quite different. Several theories, such as Technology Acceptance Model [Davis 1989], Diffusion of Innovation theory [Rogers 2003], Theory of Reasoned Action [Ajzen and Fishbein 1980], Theory of Planned Behavior [Ajzne 1982], and Social Cognitive Theory [Compeau and Higgins 1995], have been developed to explain adoption and acceptance of technologies. Among these theories, Rogers' diffusion of innovation (DOI) theory and Davis' Technology Acceptance Model (TAM) have received significant attention. TAM and DOI are quite similar in terms of identifying the perceived attributes of an innovation as key predictors explaining adoption. DOI, which was derived from a variety of studies on different innovations, identifies five perceived attributes (relative advantage, complexity, compatibility, trialability and observability) influencing the rate of adoptions. It also includes other attributes in the society that can influence innovation diffusion, such as incentives and mandates. While TAM, created specifically to explain IT adoption, proposes just two perceived attributes that influence adoption (usefulness and ease-of-use). There are many diffusion of innovation (DOI) research reported in [Prescott and Conger 1995]. Most of them investigate the evaluation, adoption, and implementation of innovations. Research has also shown that there exist gaps among values perceived from different parties in the adoption, e.g. technology provider, technology user, etc. Value compatibility has become one of the important issues for investigating adoption, diffusion and success among different parties in adoption. In [Harrington and Ruppel 1999], group values and practical compatibility were found to be a facilitator of successful adoptions. Many aspects about the nature of the new technology and the social environment need examining [Curtin, Kauffman, and Riggins 2007].

In a business research, we often see two main stream research methodologies applied, i.e. case study research methodology [Case Study 2008] or empirical research methodology [Empirical Research 2008]. Case study research methodology focuses on a specific adoption company via identifying patterns and themes. Empirical research methodology could help obtain good findings. This type of researches often need substantial data support via survey for example. However, these two research methodologies, although very useful, seem not quite suitable if used alone for developing our value analysis framework as our objective is quite clear — developing a analysis framework to bridge up the discrepancies between what can be supplied and what is expected. Thus, we would make this analysis framework open to any research methodologies. Therefore, we take a system integration approach (SIA) in developing the value analysis framework for RFID technology adoption.

Principles of This SIA Approach

The value analysis framework is meant to provide a linkage layer between what value the RFID promises and what value potential customers would like to see. This linkage layer has to be able to integrate both sides to achieve a mutual understanding. Thus, this linkage layer will be described by a set of indicators we call *value indicators*, which both sides (vendor and customer) could use to achieve mutual understanding about values.

In order to obtain these value indicators for mutual understanding to help decision making in technology adoption, SIA approach is designed with following principles: demand principle, context principle, and process principle (see Figure 1).

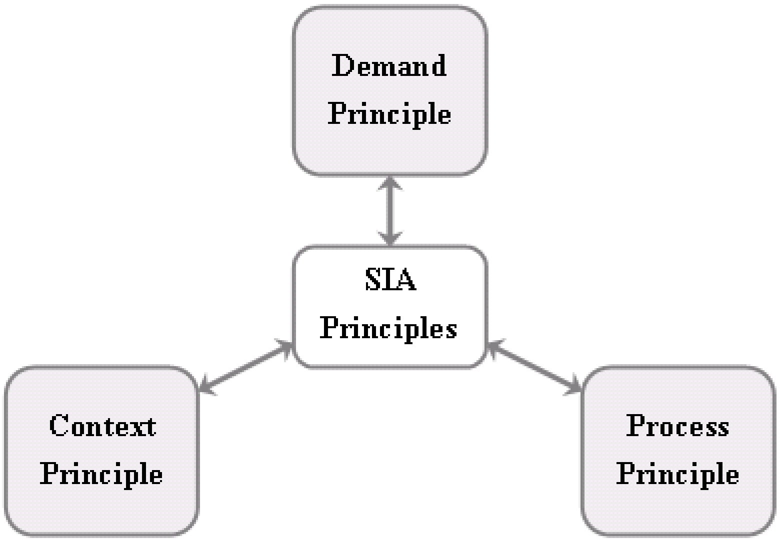

Figure 1. System Integration Approach Principles

Demand Principle

To cope with various needs for business decision making in technology adoption, there are many analysis models and tools, e.g. ROI, category analysis, developed. All these models focus on specific aspects of decision making. Although some of these analysis models or tools consider input from multidimensional perspective, they seldom span from IT system analysis to business culture analysis [Luo et al 2007]. Thus, for informed decision making, and to address the analysis gaps existing in current decision making models and tools, we have to develop an analysis tool providing a holistic view for business analysis. This holistic view has to meet the demand from technology adoption analysis needs.

The demand for value analysis in supply chain management would lead to identification of perceived value of potential customers. For example, for analyzing RFID technology adoption in logistics and supply chain management, we often need to relate those perceived value attributes with how they indicate their value whether the RFID-enabled supply chain visibility can be translated into actions to improve supply chain operation efficiency and to reduce cost. This needs an integrated view of RFID technology with supply chain business processes and applications.

Context Principle

The adoption analysis has to be conducted in a right context, forming a common background, to supply necessary data input for analysis. For example, if there is a case to analyze RFID technology adoption in supply chain management, then the context is within supply chain management. The context principle would then require a set of attributes to set up the analysis context. A selection of a reference model for logistics and supply chain management could fulfill this goal. Thus, this context principle is also referred as the *reference model principle*.

In the area of logistics and supply chain management, the Supply Chain Operations Reference-model (SCOR) [Supply-Chain Council 2006], developed by the Supply-Chain Council (SCC) provides a unique framework that links business process, metrics, best practices and technology features into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities. It forms a good reference model for conducting RFID technology adoption analysis in logistics and supply chain management including retailers.

The SCOR model has been developed to describe the business activities associated with all phases of satisfying a customer's demand. The model itself contains several sections and is organized around the five primary management processes of plan, source, make, deliver, and return. By describing supply chains using these process building blocks, the SCOR model can be used to describe supply chains that are very simple or very complex using a common set of definitions. As a result, disparate parties can be linked to describe the depth and breadth of virtually any supply chains.

Process Principle

There are many tools and models developed for business analysis. For example, SWOT analysis is often used for it provides a satisfactory business view by balancing the analysis efforts and the analysis coverage. In the market, we often have to use several analysis tools together. Thus, understanding the relationship among various analysis tools and models is the key for an integrated analysis. The relationship could be complex, though, as it could link to the processes of applying the models and tools, besides their apparent usage association in inputs and output. For example, Return on Investment (ROI) and Total Cost of Ownership (TCO) provide quite similar analysis. Typical TCO analysis provides the control function and intends to reduce the risk in capital investment. ROI analysis evaluates the potential results by the initial Investment. Through it, companies can calculate the return rate of the new projects or products.

Another example is product concept test and need assessment. Product concept test provides evaluation analysis to bring a new product into market. Need assessment finds the needs from the market. However, they are often not used at the same time. Need assessment is often used to explore the potential of the market. Out of the results if any potential exists, companies would choose to go on to the design and development stage for a new set of products. Of course, these new set of products are designed to fulfill the needs of the market. Thus, once the new products concept is developed, companies can manufacture some sample products. After that, companies can test the product to the market. The product acceptance from the market would then be observed.

The relationship among different analysis tools and models would put them in order in the analysis processes. However, the ordering could change and adapt to various analysis needs and personal habits. For example, business students start to learn the analysis sequence in their classrooms led by their business school professors. The ordering also depends on the analysis results from each tool, i.e. we have to perform one analysis to derive results before we can perform a next analysis.

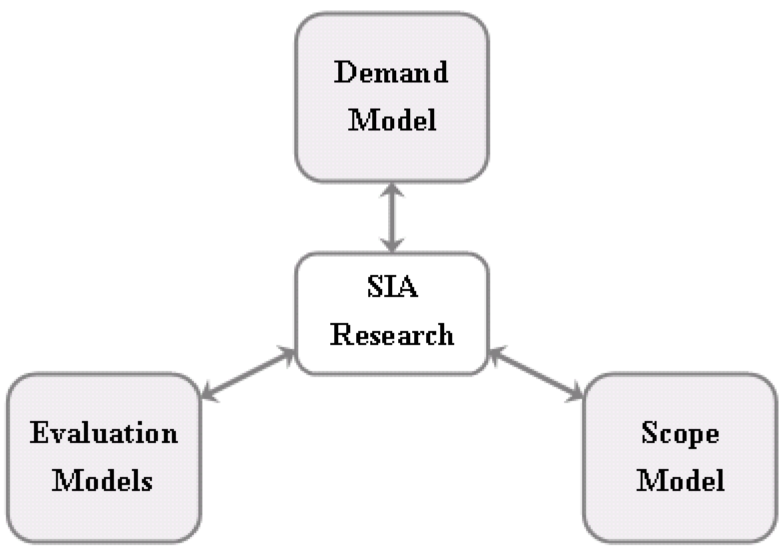

Figure 2. Research Study in System Integration Approach

Steps to Apply SIA Approach

To apply SIA approach, we have to design a research study based on the three principles. A research study via SIA approach usually involves the following (see Figure 2):

- Select models for describing elements for research demand, called demand models.
- Select models for describing scope for those elements, called scope models.
- Select models for describing evaluation for those elements, called evaluation models.

Thus, in an SIA research study, we first will have to understand the demand for SIA research, in this case, value analysis to link up both RFID vendors and potential customers. As the first step, we have to select a target leading to describe the value perception using parameters. Then, we have to put this analysis target into right adoption analysis context. Finally, processes for value parameters identification (via demand models), evaluation (via evaluation models), and prioritization (via scope models) will be formed (see Figure 2). After prioritization, we will can focus those most important parameters to set the analysis attention on a good boundary for value analysis in technology adoption.

IV. SYSTEM REALIZATION

To help RFID engagement teams to leverage this SIA-based analysis framework in approaching potential customers and to help potential RFID adopters to understand how RFID can improve their business operations, a flexible and interactive analysis environment is needed to link up various models and tools ready for use in RFID technology adoption analysis. Thus, this SIA research framework is implemented in an analysis service platform. The analysis service platform helps adoption analysis participants to make a decision on adopting RFID and its applications in an interactive manner. In this case of value analysis for RFID adoption, it could help these participants examine RFID adoption impact along supply chain based on activities referring to SCOR model and identifies the metrics of measuring the performance of supply chain.

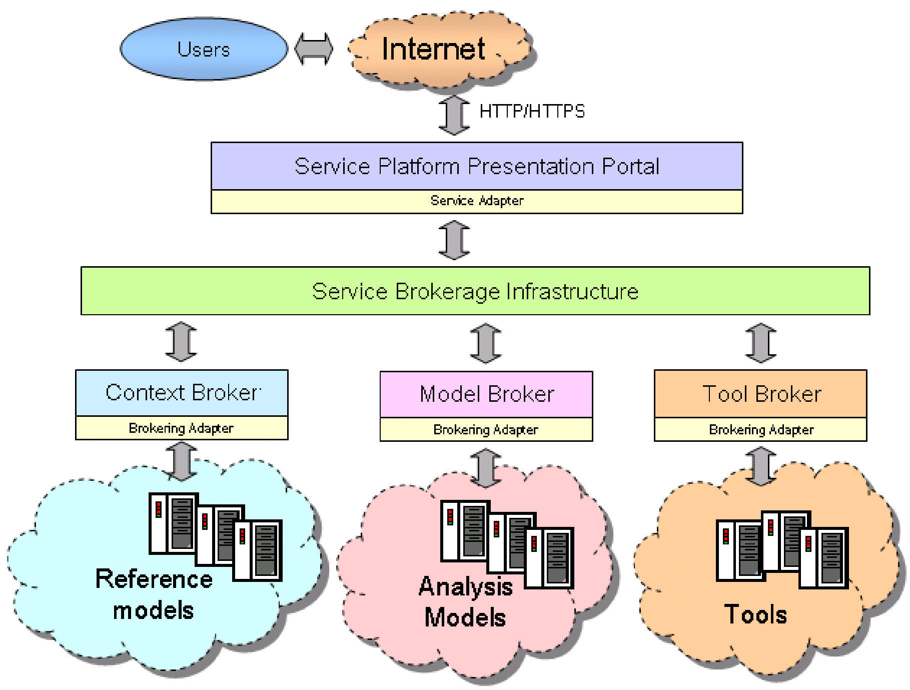

Figure 3. Value Analysis Framework Implementation System Architecture

System Architecture

The technology adoption analysis service platform (the service platform) would help bring together various models and tools to analyze RFID adoption. As shown in Figure 3, the service platform is constructed based on on-demand services infrastructure — the service brokerage infrastructure [Luo and Li 2005]. It provides technology analysis provisioning services for orchestrating data, application and execution facilities like clusters, or desktop PCs. The data services are responsible for data access including data gathering, loading, and transformation. Application services are responsible for application access. Execution services provide functions to access computing facilities.

Various business intelligence services including data mining and knowledge discovery would be available in this platform.

The key functional components in this service platform are the context analysis, model analysis, and tool analysis. They together provide services to provide an interactive interface for analysis participants to evaluate perceived value from different technology adoption parties. To cope with various needs for business decision making in technology adoption, context analysis helps set the right context to form a common background to supply necessary data input for adoption analysis. In this retail RFID study, the SCOR model provides a good reference for conducting RFID adoption analysis in logistics and supply chain management. Model analysis will help select the right analysis models and identify the relationship among different analysis models and put them in order in the analysis processes. Tool analysis will help provide an integrated tooling to perform adoption analysis.

Participation Models

The service brokerage infrastructure will help form the right analysis process according to demanded technology adoption analysis. The analysis process will take input relevant to the potential adopter's businesses to drive the adoption analysis. Like other business intelligence, statistical, and benchmarking exercises, the analysis data input to the service platform has great impact on the adoption analysis results. The technology adoption analysis process would involve multiple parties for multi-party collaborations. To suit different operating behavior of each participating party, the service platform provides several operation models, i.e. online, offline, and hybrid participation. These three types of operation models will help address the concerns about protecting the privacy of individuals as well as companies' trade secret involved in the adoption analysis.

- Online participation: In this way, participants log in to the service platform portal and load data to the tools in the service platform to conduct adoption analysis. In this operation model, processes for conducting adoption analysis will be provisioned, composed, and executed in the service platform portal.
- Offline participation: In this way, the technology adoption analysis tools are downloaded to the local environment of the platform participants. When these participants process their analysis data, it is not necessary for them to upload their data into service platform. In this operation model, processes for conducting adoption analysis will be provisioned and composed in the service platform portal. The processes will then be downloaded into the participants' local environment for execution.
- Hybrid participation: In this way, participants could choose to log in to the service platform portal and load data to the tools in the service platform to conduct adoption analysis. Or they can choose to execute the process in the participants' local environment. Furthermore, they can select partial processes executed in the service platform, and the rest of the processes in the local environment.

Analysis Processes

To construct the adoption analysis, we have to form the right analysis process to link up the context, analysis models, and tools for value indicator identification. An example of such a process is as follows. In this analysis process, it will first conduct needs (demand) assessment for RFID. Once the need is confirmed positive, the next step would be the SWOT analysis from which an initial plan for RFID adoption would be derived. A few more analyses could come along. For example, category awareness and category viability assessment could be applied. If the category is not the best, decisions could be made as to limit the scope of the RFID introduction or terminate RFID introduction. Early adopter indentation and adoption curve placement could also be in the analysis process. This will help to identify the early adopter of the RFID technology. Product concept testing could be also used for IT companies if they would like to analyze whether or not to start an RFID product.

V. AN ILLUSTRATION

In this section, we will illustrate an analysis process to demonstrate the value analysis for RFID technology adoption in retailers in China. This could serve as the purpose to show the feasibility of our proposed SIA approach. Such an illustrative process is shown in Figure 4.

Preparation — Demand Analysis

In the analysis processes, the retailer RIC example is used in the illustration. To simplify the illustration, we will illustrate implementation of this process through studying RFID adoption in retailers in China. We will place the retailer RIC in a three-echelon supply chain to identify potential impacts from RFID adoption on the retailers. The dynamic behaviors of the supply chain, which are affected by deployment of RFID technology are as follows:

- In the manufacturer, RFID tags are read at the points of production and shipping.
- In the distribution center, RFID tags are read at the receiving and shipping docks.

- In the retailer, tag reading occurs at receiving, the backroom and the shelf in the store.

It can be easily seen that without RFID, the inventory reduction due to shrinkage is not known in a real-time manner, and the retailer's replenishment decision is made based on the inaccurate inventory information. With RFID, shrinkage occurs as before, but the replenishment decision is expected to improve due to more accurate inventory information, thus improving the supply chain performance.

Output of the preparation will be the demand requirements, i.e. whether or how retailer RIC benefits from the RFID adoption and the impact on the retailer operational processes.

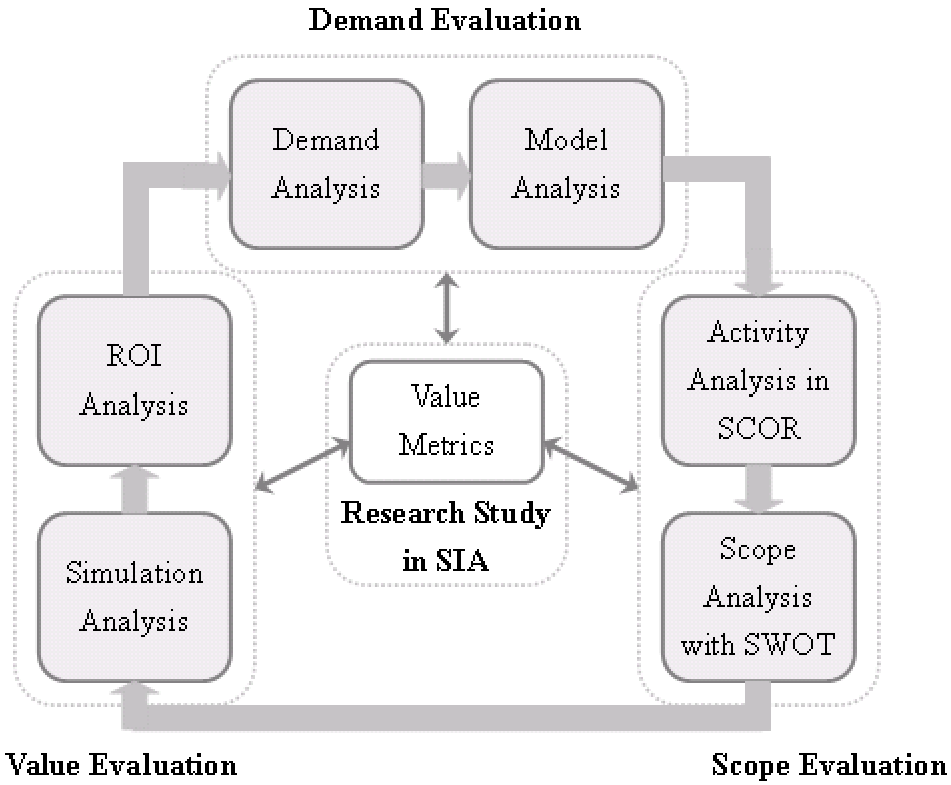

Figure 4. A Process for Value Analysis in Retailers in China for Illustration

Initialization — Model Analysis

Input to the initialization for RFID adoption analysis include demand requirements. This information will be available all along the adoption analysis processes. Now the analysis processes are formed. Scope model is assisted with SWOT. ROI and simulation are used in value evaluation.

With those models and tools, the analysis framework examines the RFID adoption impact along the supply chain based on activities referring to SCOR model and identifies the metrics of measuring the performance of the supply chain. Then it employs SWOT analysis to focus the adoption analysis within a reasonable scope. Based on the identified metrics from the SCOR reference model, the benefits, costs, and risks of target RFID application (simulated) would be identified. Adoption analyst can even further calculate the expected ROI with the benefit, cost, and risk figures.

Thus the analysis framework can help identify how RFID brings value to retailer RIC. While the whole chain could be analyzed for adoption potentials, the analysis could be conducted on different segments of the supply chain to evaluate individually how each can take advantage of RFID technology. It is expected that there will be interplay among different players and different chains. For example, retailer RIC piloting RFID programs reports improved sales from greater stock availability, cost savings, and increased responsiveness, especially in receiving and inventory control operations. As these applications continue to prove their value, more retailers are expected to announce compliance tagging requirements, so many manufacturers may find themselves being asked or required by a retail customer to apply RFID tags to shipments.

Outputs of initiation for RFID adoption analysis include adoption analysis processes setup and tools/models (DOI, SWOT, etc.) to be used.

Activity Analysis

Besides the output from earlier stage, inputs to the activity analysis include SCOR retailer operational process and activity definitions. Retailer RIC sits at the very end in the supply chains, resulting in its sensitivity to the changes and fluctuations of the supply chains it participates by introducing RFID. To examine the impact of RFID on the whole supply chain is not a simple task. The activity-based costing is based on the concept of allocating the indirect and overhead cost to the activity level so as to improve the accuracy of cost accounting. Hence we intend to "allocate impact" of RFID on the RIC supply chain based on supply chain activities. Based on RIC supply chain, according to the interaction and relationship among the activities defined in SCOR model [Supply-Chain Council 2006], we first classify them into different categories, based on the criteria whether RFID adoption would lead any potential impact on them. The activity categories are identified in Table 1, including product tracking, receiving and shipping, asset management, inventory control, packaging, shelf management and check out, data collection, regulation and customer requirement compliance, and returns management. Activity categories of Table 1 will be sent to the following analysis stage to identify metrics to evaluate RFID adoption impact.

Table 1. Activities Categories and Value Activities

Category	Activity	
Production Tracking	M1.2/M2.2/M2.3 Issue Material	M1.3/M2.3/M3.4 Produce and Test
	M1.5/M2.5/M3.6 Stage Product	EM.4 Manage In-Process Products (WIP)
	EM.6 Manage Transportation	EM.7 Manage Production Network
Receiving & Shipping	S1.2/S2.2/S3.2 Receive Product	S1.3/S2.3/S3.3 Verify Product
	S1.4/S2.4/S3.4 Transfer Product	ES.6 Manage Incoming Product
	D1.8/D2.8/D3.8 Receive Product from Source or Make	D1.9/D2.9/D3.9 Pick Product
	D1.12/D2.12/D3.12 Ship Product	D4.2 Receive Product at Store
Asset management	EM.5 Manage Equipment and Facilities	ED.5 Manage Deliver Capital Assets
Inventory Control	ES.4 Manage Product Inventory	D4.1 Generate Stocking Schedule
	ED.4 Manage Finished Goods Inventories	
Packaging	M1.4/M2.4/M3.5 Package	D1.10/D2.10/D3.10 Pack Product
Shelf Management & Check Out	D4.3 Pick Product from Backroom	D4.4 Stock Shelf
	D4.6 Checkout	
Data Collection	P4.1 Identify, Prioritize, and Aggregate Delivery Requirements	
	ES.2 Assess Supplier Performance	ES.3 Maintain Source Data
	D1.11/D2.11/D3.11 Load Vehicle & Generate Shipping Documentation	
	ED.2 Assess Delivery Performance	ED.3 Manage Deliver Information
Regulatory and Customer Requirement Compliance	ES.8 Manage Import/Export Requirements	
	EM.8 Manage Regulatory Compliance	ED.8 Manage Import/Export Requirements
Returns Management	DR1.3 Receive Defective Product	DR2.3 Receive MRO Product
	DR3.3 Receive Excess Product	

Metrics Identification

Input to this stage will be activity categories. From these activity categories, we would further identify value activities which have potential RFID impact, shown in Table 1. For example, in Inventory control category, there are activities like ES.4 Manage Product Inventory, D4.1 Generate Stocking Schedule, and ED.4 Manage Finished Goods Inventories. These activities are identified and included because real-time RFID data could potentially lead to timely information for managing various inventories, either to reduce the inventory level or the lead time to generating stocking schedules.

Based on the value activities, we further identify the metrics for evaluating the RFID adoption impact. Similar to the activity-based costing concept of allocating the indirect and overhead cost to the activity level, we "allocate impact" of RFID on the RIC supply chain based on value activities to identity metrics for impact evaluation.

A general type of metrics is defined for evaluating the RFID system such as reliability, complexity, user friendliness, and durability in harsh environments, as they are pervasive for any RFID adoption. These metrics exist in the whole supply chain (i.e. in every activity impacted by RFID adoption), so we group them in a general category. We also have to identify the metrics for each activity category based on the value activity identified for impact evaluation. For example, the inventory control includes Cost to Manage Inventory, Manage inventory cycle time, etc. (see Table 2). Description for each metrics is also given (see Table 2). Content of Table 2 will be the output of this stage.

Table 2. Metrics for Value Activities in Supply Chain

Category	Metrics	Description
General (RFID System)	System Reliability	The performance of RFID system in reading data correctly, processing data correctly, exchanging data correctly, querying data correctly, etc.
	Deployment Complexity	The complexity of deploying a RFID system, including the cost of capital and labor, the connection with existing systems, and so on.
	User Friendly	The convenience of the RFID system, including interface friendly, the portability of RFID reader, etc.
	Durability in Harsh Environment	The durability of the RFID system in hash environment, e.g. humid, high temperature, high pressure.
Production Tracking	Manufacture Variability	The condition that occurs when manufacture is not consistently repeatable either in quantity, quality, or combination of these.
	Goods Inventory Days	Five-point annual average of the sum of all gross inventories (raw materials & WIP, plant FG, field FG, field samples, other) ÷ (annual cost of goods sold ÷ 365).
	Cost to Manufacture	The sum of the costs associated with manufacture activities.
	Manufacture Cycle Time	The average time associated with manufacture activities.
Receiving & Shipping	% Orders Processed Complete	The number of orders that are processed complete divided by the total orders processed within the measurement period.
	% Orders Delivered on Time	The number of orders that are received on time to the demand requirements divided by the total orders for the demand requirements in the measurement period.
	% Orders Received with Correct Shipping Documents	The number of orders that are received on time with correct shipping documents divided by the total orders processed in the measurement period.
	Delivery Cycle Time	The average time associated with delivery activities.
	Cost to Delivery	The sum of the costs associated with delivery activities.
Asset Management	Cost to Asset Management	The sum of the costs associated with asset management activities.
	Asset Management Cycle Time	The average time associated with asset management activities.
	Asset Utilization	A measure of how intensely an asset is being used.
Inventory Control	Cost to Manage Inventory	The sum of the costs associated with inventory control activities.
	Manage Inventory Cycle Time	The average time associated with inventory control activities.
	Goods Inventory Days	The average of the sum of all gross inventories. Total gross value of inventory at standard cost before reserves for excess and obsolescence.
	% of Orders Delivered in Full	Percentage of orders which all of the items are received by customer in the quantities committed. [Total number of orders delivered in full] / [Total number of orders delivered] x 100%
	Theft lost	The sum of lost associated with theft crime.
Packaging	Cost to Packaging	The sum of the costs associated with packaging activities.
	Packaging Cycle Time	The average time associated with packaging activities.
Shelf Management & Check out	Cost to Shelf Management & Check out	The sum of the costs associated with shelf management & check-out activities.
	Shelf Management & Check-Out Cycle Time	The average time associated with shelf management & check out activities.
	In-stock %	Percentage of goods that are there when needed.

	% Item Location Accuracy	Percentage of goods that are at the right place.
Data Collection	Cost to Data Collection	The sum of the costs associated with data collection activities.
	Shelf Management & Check-Out Cycle Time	The average time associated with data collection activities.
	Data Collection Accuracy	Percentage of data that is correct.
Regulatory and Customer Requirement Compliance	Cost to Regulatory and Customer Requirement Compliance	The sum of the costs associated with regulatory and customer requirement compliance activities.
	Regulatory and Customer Requirement Compliance Cycle Time	The average time associated with regulatory and customer requirement compliance activities.
Returns Management	Cost to Receiving Return	The sum of the costs associated with receiving return activities.
	Receiving Return Cycle Time	The average time associated with receiving return activities.

SWOT Analysis

Input to the SWOT analysis includes the metrics identified. With these metrics at hand, questions arise such as which metrics are more important? Is it possible assign weight to them? To address this, we have to identify key metrics that matter to the retailer RIC. These key metrics are also called *key value indicators*.

To do this, we conduct SWOT analysis on RFID adoption by putting those metrics in the four categories in the SWOT table. This is useful because each category in SWOT might be examined differently in different DOI transition stages. As we know, inventory management is one of the key value activities for retailers. Thus, as an illustration, we pull out the metrics from the identified general and inventory management specific management metrics, and then assign them to the SWOT table (see Table 3). Based on the RIC supply chain, we can then identify their strengths, weaknesses, opportunities, and threats in the SWOT analysis to help scope the adoption analysis. In another word, we assign weights to each of them to understand the importance of these metrics to the retailer RIC.

Table 3 SWOT for Scope Analysis

Strength	**Weakness**
Easy to use Durable – can be used in harsh environments Reduces labor cost Avoid potential lost from theft or inappropriate movement Shorter inventory cycle time Automatically report generating	Complexity of deployment (e.g. Interface with other information systems needed) High set-up cost System maintenance needed Interference from other wireless technologies Clearing inaccurate data needed
Opportunities	**Threats**
High order fulfillment helps to improve customer loyalty High efficiency in logistics helps to outperform competitors Push partners to adopt RFID and thus achieve even higher efficiency	Standards are not matured Privacy issues

From the above SWOT table, we select the attributes which have non-negligible impact on the revenue or expense of retailer RIC based on the dynamic behavior by introducing RFID into the operations. These attributes are weighted so the priority of each could be ranked. Then a profit-cost-risk analysis is conducted in order to generate the key value indicators, i.e. those key metrics with higher rankings. We identify which can increase revenue, which can reduce costs and which can avoid costs and group them as the benefits that are incurred by RFID adoption. For example, there are one-time and recurring costs of installing and maintaining an RFID system. Moreover, we go on identifying the possible risks from the SWOT analysis. The benefits and costs, together with these risks, will facilitate further ROI analysis.

We rank each attribute in the SWOT matrix and allocate reasonable probabilities to them according to the retailer RIC's business operations. For example, we regard a system with plug-and-play property has zero percent complexity of deployment and a system which requires a total reengineering of all the interfaced systems has a 100 percent complexity of deployment. So we consider the complexity of deployment as 60 percent when 60 percent of the interfaced systems need to be reengineered according to the state of art in RFID technology development in China. And for the second attribute in the strengths pane, the durability is considered to be 100 percent if RFID tags are durable under whatever environment. In the same way, we get all the probabilities on all the attributes listed in the SWOT matrix and thus generate our extended SWOT analysis table as shown in Table 4.

Table 4 Prioritization in Extended SWOT Analysis

Strength	**Weakness**
Easy to use (PS1=80%) Durable – can be used in harsh environments (PS2=80%) Reduces labor cost (PS3=30%) Avoid potential lost from theft or inappropriate movement (PS4=10%) Shorter inventory cycle time (PS5=60%) Automatically report generating (PS6=80%)	Complexity of deployment (e.g. Interface with other information systems needed) (PW1=80%) High set-up cost (PW2=90%) System maintenance needed (PW3=100%) Interference from other wireless technologies (PW4=40%) Clearing inaccurate data needed (PW5=20%) Labor cost to add tags to items (PW6=80%)
Opportunities	**Threats**
Customer loyalty improved by high order fulfillment (PO1=60%) High efficiency in logistics helps to outperform competitors (PO2=70%) Push partners to adopt RFID and thus achieve even higher efficiency (PO3= 30%)	Standards are not matured (ST1=30%) Privacy issues (ST2=30%)

The probabilities in Table 4 are added according to the retailer RIC supply chain operations, the state of art in RFID technology development, and DOI adoption stage. These probabilities assigned most likely would vary from case to case, from company to company, and from time to time. RIC can make its own decision on the probabilities according to their situation (such as innovator DOI adoption stage) and make adjustment when necessary according the new development in RFID technology and their supply chain operations.

Simulation Analysis

Inputs to the simulation include the key metrics and content in Table 4. To further validate the probabilities assigned, and to further understand how key metrics matter to the retailer RIC, we will leverage the tools from [Lee, Cheng, and Leung 2004] to demonstrate the different supply chain behavior under different operational policies. The assumption about the supply chain for RIC is made as follows:

- Products in the retailer are sold to customers with equal probability.
- Customers arrive according to a log-normal distribution, and their purchase quantity on each purchase occasion is assumed to be uniformly distributed.
- The store replenishment is based on a policy considering a balance between the reorder point (P) and target inventory (T).
- For the manufacturer, it is assumed that the daily production quantity for each product is decided based on a certain policy, and is shipped to DC once a day.
- The lead time for shipment from manufacturer to DC is one day. For the DC, the products are pulled from the retailer based on the retailer's replenishment policy and frequency. The lead time for shipment from DC to retailer is one day.

Through the simulation, the dynamic effects of RFID on RIC supply chain performance could be analyzed. In the simulation, three cases are studied with different replenishment policy. One case is where RFID technology is not deployed and two cases where RFID technology is deployed. Without RFID, the inventory reduction due to shrinkage is not known, and the retailer's replenishment decision is made based on the inaccurate inventory information. With RFID, shrinkage occurs as before, but the replenishment decision is expected to improve due to more accurate inventory information, thus improving the supply chain performance.

Further, we can tune the simulation model by changing the input, taking the accuracy of the data into consideration. As we can see from the SWOT analysis in Table 4, if "clearing inaccurate data needed" has "PW5=20 percent," which can be interpreted as that in less than 20 percent, situations clearing inaccurate data is needed. If we further interpret this as 20 percent data is inaccurate due to RFID misread, then we can further put down the change range of the data (see Table 5). It can be easily seen that with 20 percent data inaccurate, average inventory in retailer RIC have overlap areas in three case. That means, introducing RFID would not bring too much value unless inaccurate data is removed beforehand, until RFID technology improves (see Table 5). On the other hand, it is possible to put together a cluster of RFID readers to improve the correct read rate. However, this would certainly introduce additional cost. In view of this, an ROI analysis to study potential return is needed.

Furthermore, from the Table 5, it could be seen that it simple introduction of RFID will not yield the desired result unless the RFID is supported by a good operational policy. That is, business process reengineering is often needed. Thus, it is encouraged to put all metrics with probability into the simulation process to show visible changes. When the probabilities change, the simulation process can be re-run to get up-to-date results. We can tailor make the simulation process according to new replenishment policy and other new situations. Through this simulation activity, retailer RIC could get a good picture about the impacts of RFID adoption under different situations. It also helps them to identify key metrics or key value indicators they shall pay attention to.

Table 5 Summary of Benefits of RFID Adoption from Simulation

	Without RFID	With RFID	With RFID
Replenishment Policy(P,T)	P=36, T=48	P=36, T=48	P=26, T=38
Retailer Avg. Inventory	22.58 (27.096~ 18.064)	27.11 (32.353~21.688)	17.24 (20.688~13.792)

ROI Analysis

Inputs to the ROI analysis include the key value indicator identified and the simulation results. Through ROI exercise, retailer RIC could obtain quantitative results for impact evaluation under different RFID adoption cases. Suppose the life cycle of the RFID system is N years, the following table (see Table 6) demonstrates the way to get the return on investment for inventory control in retailer RIC. It is the normal ROI calculation. What we have done is group the metrics into two categories, i.e. benefit and cost. Three categories are classified as subcategories in benefit group based on whether they would increase revenue, reduce cost, or avoid cost. Two categories are classified as subcategories in cost category. To simply the illustration, assume that all the figures in Table 6 are present value adjusted by interest rate already. The revenue and cost are assigned to those metrics according the activity based accounting principles.

Based on calculation method in Table 6, we can obtain the benefits from RFID adoption in inventory control by using the number obtained from simulation. While the cost of setup and maintenance of the RFID system can be evaluated by RFID solution providers. From the data which is gathered from simulation and solution providers, we can feed them into the ROI analysis model in Table 6 and get the ROI of the first year and the average ROI during N years. The retailer can adjust the reorder point or the lead time to find a tradeoff among inventory keeping cost, order fulfillment rate, and return on investment.

For a simple illustration, in the inventory control activity for retailer RIC, if we have to reduce the misread rate from 20 percent to 0, a cluster of four readers (5000HKD each) are needed in a single control point. In the retailer RIC, tag reading occurs at receiving, the backroom and the shelf in the store. There are 4*3 = 12 readers (60000HKD) to be deployed. This will incur additional professional service charge (10000HKD one time charge plus monthly maintenance fee 2000HKD) for further tuning the reader cluster toward a good working mode. Assuming that by reducing the average inventory from 22.58 to 17.24, inventory keeping cost and related labor cost could be reduced by 50000HKD. Thus, in the first year, RIC would record net benefit 50000 – 60000 – 2000*12 = - 24000HKD. A negative ROI (-24000/50000 = -48 percent) will occur in the first year. It could be easily calculated that RIC would record a positive ROI in simply three years.

Table 6 ROI Analysis of RFID Application in Inventory Control

ROI of RFID in Inventory Control		**Year 1**	**Year k**	**Year N**
1- BENEFITS				
A	Increased revenue			
	Increase order fulfillment rates	A_{11}	A_{k1}	A_{N1}
	Increase customer loyalty	A_{12}	A_{k2}	A_{N2}
B	Reduced costs			
	Inventory keeping cost	B_{11}	B_{k1}	B_{N1}
	Warehousing and delivery labor	B_{12}	B_{k2}	B_{N2}
C	Avoided costs			
	Labor (counting, data collection)	C_{11}	C_{k1}	C_{N1}
	Potential damage	C_{12}	C_{k2}	C_{N2}
	Reporting	C_{13}	C_{k3}	C_{N3}
D	Annual benefits = **(A+B+C)**	$D_1=\sum A_{1i}+\sum B_{1i}+\sum C_{1i}$	$D_k=\sum A_{ki}+\sum B_{ki}+\sum C_{ki}$	$D_k=\sum A_{Ni}+\sum B_{Ni}+\sum C_{Ni}$
	Cumulative value	CD_1	$CD_k= D_1+\ldots+D_k$	$CD_N= D_1+\ldots+D_N$
2 – COSTS				
E	One time costs			
	Server	E_{11}	0	0
	Database	E_{12}	0	0
	Deployment	E_{13}	0	0
	Project management	E_{14}	0	0
	Readers and other hardware	E_{15}	0	0
F	Recurring costs			
	Tags	F_{11}	F_{k1}	F_{N1}
	System administration	F_{12}	F_{k2}	F_{N2}
	Network and security	F_{13}	F_{k3}	F_{N3}
	Maintenance and development	F_{14}	F_{k4}	F_{N4}
G	Annual costs **= (E+F)**	$G_1=\sum E_{1i}+\sum F_{1i}$	$G_1=\sum F_{ki}$	$G_1=\sum F_{Ni}$
	Cumulative costs	CG_1	$CG_k=G_1+\ldots+G_k$	$CG_N=G_1+\ldots+G_N$
NET VALUE				
H	Annual net benefits = **(D-G)**	$H_1=D_1-G_1$	$H=D_k-G_k$	$H_N=D_N-G_N$
I	Cumulative total	$I_1=H_1$	$I_k= H_1+\ldots+H_k$	$I_N=H_1+\ldots+H_N$
ROI = **H/G** (first year)		$H_1/ \lvert G_1\rvert$		
ROI Average = **I/G** (total)		$I_N/ \lvert CG_N\rvert$		

The ROI exercise would yield expected return under different RFID adoption cases. The ROI results together with the simulation results would help retailer RIC to make a rational decision on whether they should invest on RFID systems or follow each adoption case.

When ROI exercise is complete, the analysis process ends presenting a good picture about the how different factors could affect RFID adoption. Thus, it could lead to informed decision making regarding whether to adopt RFID or not, or even generate a right adoption roadmap.

VI. ASSESSMENT

In the illustration, we have constructed analysis processes taking the following input like technology development level, internal human resource, and external connections faced by retailers in China into analysis consideration to help the adoption analysis.

- Technology development level
    - o Multiple RFID standards
    - o RFID technology readiness
    - o IT infrastructure readiness
    - o Cost of RFID implementation
- Human resource
    - o Labor cost
- External connections
    - o RFID value chain
    - o Outsourcing environment

In the illustrated example, we have shown technology development level has a strong impact over the value perceived by retailers. For example, the RFID miss read rate, could easily smooth out any advantages by adopting RFID in inventory control in retailer RIC. This leads to a situation where adoption of RFID would not yield solid gain to the benefits of retailer RIC unless the RFID misreads rate drops. The illustration has also demonstrated that RFID adoption shall come with right business process reengineering to transform the business operations in the retailer to benefit from RFID innovation. The illustration is based on assumption that RFID value chain exists such that manufacturers, distribution centers and retailers can all source and deploy interoperable RFID and standards in their operating environment.

Feedback from the Industry

Our extensive engagement with companies in Hong Kong and Pearl River Delta (PRD) in China shows that retailers in China started getting interested in RFID technology. The relatively closer supply chain coupling among supply chain participating companies yields potential demand for RFID technology in this region. This analysis framework is in fact drawn from the experiences in their engagement in their projects. To evaluate this framework, we conducted extensive information exchange with the business and technical teams of these companies:

- In RFID-related projects, SWOT has been used to illustrate the strength, weakness, opportunities, and threat of corresponding projects. However, all of the SWOT exercises are conducted in an ad hoc manner. Thus, insights from the SWOT exercises very much depends on the skills and experiences of the people who conducted the exercise. All of them think the reference model is very helpful to provide needed context for the SWOT exercises.
- These people have shown interest in this analysis framework and wondered if it could take their business operating processes as input, and create familiar analysis processes leveraging various methods and models available from the framework. The interactive feature of the analysis framework makes it a good assistant in delivering a nice sales presentation.
- As mentioned, there are about 80,000 factories located in PRD with Hong Kong connections. Many of them are small- and medium-sized (SME) companies. They have acquired industry knowledge about their business, which often focuses on a very specific domain. They often do not have enough business skills to conduct extensive technology adoption analysis. A good way to handle this problem is to source these kind of analysis skills with help from IT tools for conducting the analysis activities. Therefore, our analysis framework fits naturally to fulfill the needs of these companies.
- Moreover, the very low level of IT capability of these SME logistics companies and expensive Total Cost of Ownership (TCO) of IT systems make the IT systems unaffordable to them. Thus, many of them are very interested in a service platform implementation to put IT functions such as the analysis framework to use. The analysis framework implemented in the analysis service platform offers flexible operation models for SME companies to participate either through subscription or downloading to their own IT environment.

Open and Flexible Framework

In business research, we often see two mainstream research methodologies applied, i.e. case study research methodology [Case Study 2008] or empirical research methodology [Empirical Research 2008]. Case study research methodology focuses on a specific adoption company via identifying patterns and themes. Empirical research methodology could help obtain good findings. These type of researches often need substantial data support via survey for example. However, these two research methodologies, although very useful, seem not quite suitable if used alone for developing our value analysis framework as our objective is quite clear – developing a analysis framework to bridge up the discrepancies between what can be supplied and what are expected. Thus, we would make this analysis framework open to any research methodologies. Therefore, we take a system integration approach (SIA) in developing the value analysis framework for RFID technology adoption.

As pointed out earlier, several theories, such as Diffusion of Innovation theory [Rogers 2003], the Technology Acceptance Model [Davis 1989], the Theory of Reasoned Action [Ajzen and Fishbein 1980], the Theory of Planned Behavior [Ajzne 1982], and Social Cognitive Theory [Compeau and Higgins 1995], have been developed to explain adoption and acceptance of technologies.

These works especially DOI, SCOR, and activity based accounting (ABC) all could be utilized in our adoption analysis. TAM and DOI identify the perceived attributes of an innovation as key predictors explaining adoption. Other works in analyzing RFID adoption echoing this point out that many aspects about the nature of this new technology and the social environment need examining [Curtin, Kauffman, and Riggins 2007].

Further, our framework is based on processes to orchestrate available adoption analysis tools toward achieving an comprehensive analysis results. Thus, it complements existing available analysis models and tools, and turns them into useful modules in an coherent manner in an integrated analysis environment.

Interactive Analysis Feature

The analysis framework further provides interactive analysis capabilities which allow users to adjust input to each step in the analysis processes, leveraging available theories and tools. For example, during the adoption analysis such as SWOT, simulation, and ROI, DOI stage transition analysis would help analyzer to grasp the potential movement directions for important metrics. The movement trend is obtained through evaluating the impact when RFID adoption transits from one stage to another. The movement direction of the SWOT matrix and ROI when the RFID adoption passing its five stages is shown in Table 7. In Table 7, the general tendency is given, in light of the individual metric may behavior differently. Thus, Table 7 only provides possible movement on adjusting probabilities during simulation or ROI analysis in different stages.

Table 7 Changes in Different Stages in DOI

Stage	Overall Tendency of Probabilities in SWOT-P *		Average ROI *	Remarks
Innovator	PS ↑	PW ↓	↑	The opportunities in this stage are not quite obvious.
	PO → or ↑	PT → or ↓		
Early adopters	PS ↑	PW ↓	↑	The technology keeps evolving. Advantages are strengthening. Drawbacks are being overcome.
	PO ↑	PT ↓		
Early majority	PS → or ↑	PW → or↓	Hard to anticipate	The technology is quite matured. The long-term ROI is hard to anticipate.
	PO →	PT ↓		
Late majority	PS →	PW →	↓	New threat may appear such as new technology comes forth.
	PO →or ↓	PT → or ↑		
Laggards	PS →	PW →	↓	The technology is not new any more, thus may be substituted by newer technology in some time.
	PO ↓	PT ↑		

- ↑ stands for the probabilities increase
- ↓ stands for the probabilities decrease,
- → stands for the probabilities remain unchanged.

Furthermore, Table 7 only accommodates the stage definition from DOI theory and the situation of RFID adoption. When the probability of one attribute decreases to zero percent or a threshold which can be defined by the decision-maker, this attribute may be removed or shift to another category (e.g. an opportunity may shift to a threat). The SWOT may differ from one enterprise to another because of the different objectives they want to achieve. When the SWOT changes, the ROI can be recalculated following our adoption framework. With this tool, the decision-makers could obtain more comprehensive knowledge about the new technology and more confidence when run the adoption analysis.

Let us come back to the SWOT analysis on inventory control in Table 4. As long as the technology matures, the complexity of deployment will keep on decreasing. We can anticipate the tendency of the probability movement after Table 8 shows our analysis on how the probabilities in the SWOT matrix in Table 4 will change when the RFID adoption expanding from innovator stage to early adopter stage in China. The attributes which are remain unchanged are not included in this table.

Table 8: The Change of SWOT Matrix when RFID Adoption expands from Innovator Stage to Early Adopter Stage in China

	P during innovator stage	P during early adopter stage	Tendency	Remarks
Strengths				
- Reduces labor cost	PS4	PS4'	PS4<PS4'	When the whole market adopts RFID, it can reduce labor cost further.
Weaknesses				
- Complexity of deployment	PW1	PW1'	PW1>PW1'	When the technology matures, the complexity will decrease.
- High set-up cost	PW2	PW2'	PW2>PW2'	The cost of tags and reader is going down
- Interference from other wireless technologies	PW4	PW4'	PW4>PW4'	RFID standards are going to be published in China. This problem will have less influence.
- Clearing inaccurate data needed	PW5	PW5'	PW5>PW5'	Less interference will lead to less inaccurate data.
Opportunities				
- Push partners to adopt RFID and thus achieve even higher efficiency	PO3	PO3'	PO3≤PO3'	The chance will be better when more early adopters appear.
Threats				
- Standards are not matured	PT1	PT1'	PT1≥PT1'	The standards are going to be published. Maybe it is not a threat any more.

The tendency from early adopter stage to early majority stage will be different from the above table, so it is important to identify the adoption stage first before we review on the RFID application decision-making process. When the internal and external environments change, we can change and adjust the parameters to be fed into the simulation model and re-run the simulation process.

Summary—Unique Features

In summary, our analysis framework is open to any research methodologies. We take a system integration approach (SIA) in developing the value analysis framework for RFID technology adoption. While the feasibility of our analysis framework is illustrated, its novelty is further demonstrated in the following:

- The framework utilizes analysis processes to conduct the technology adoption analysis. This brings unique advantages to flexibly construct adoption analysis to entertain different analysis requirements. Modern technology adoption analysis is becoming more and more complicated, facing the needs for domain knowledge to examine various aspects related to the technology and the social environment. The approach would allow us to provide a flexible environment to conduct modern technology adoption analysis.
- The framework is open to new technology analysis models and methods. In the open integrated environment, our analysis framework is able to embrace new discovery and development in analysis models and methods.

- Further, the framework provides interactive analysis capabilities which allow users to adjust input to each step in the analysis processes. For example, in the illustration, during the adoption analysis such as SWOT, simulation, and ROI, DOI stage transition analysis would help analyzer to grasp the potential movement directions for the metrics and key value indicators. With this tool, the decision-makers could obtain comprehensive knowledge about the new technology and more confidence to run the adoption analysis using this framework.

And this analysis framework can address the following challenges faced by retailers in China:

- Although many retailers in PRD have acquired industry knowledge about their business, which often focus on a very specific domain. They often do not have enough business skills to conduct extensive technology adoption analysis. A good way to handle this problem is to source these kind of analysis skills with help from IT tools for conducting the analysis activities. Therefore, our analysis framework fits naturally with the needs of these companies.
- Moreover, the very low level of IT capability of these SME logistics companies and expensive Total Cost of Ownership (TCO) of IT systems make the IT systems unaffordable. Thus, many of them are very interested in a service platform implementation to put IT functions such as the analysis framework for use. It offers flexible operation models for SME companies to participate either through subscription or downloading to their own IT environments.

VII. CONCLUSION

The incentives and mandates issued by Chinese government contribute a lot to the diffusion of RFID adoption in China. For example, in 2006, the Ministry of Science and Technology of China launched a scheme of “RFID Technology and Application” within the Hi-tech Research and Development Program of China (863 Program), which offered funding for 19 successfully applied projects, covering various aspects of RFID technology, including retailer applications. China government agencies have also been encouraging product manufacturers to implement RFID. The China National Tobacco Monopoly Administration requires every one of its 37.5 billion cigarette packages to be identified with brand, type, and origin, and this information is stored on a central database. Hangzhou Cigarette Factory first completed the RFID Finished Product Warehousing Management System in 2005. After that, Chongqing Tobacco Factory [Li L. 2007] developed an RFID Supplementary Materials and Finished Product Roboticized Logistics System, and Kunming Tobacco Company [Ping 2007] developed an RFID Digital Warehouse in 2006.

Moreover, as part of the global economy, China’s manufacturers are mandated or encouraged by their global buyers to implement RFID. This helps the formation of the value chains for RFID adoption in China, where retailers in China can benefit from. In turn it will help form a larger RFID adoption ecosystem, facilitating RFID adoption in various players in logistics and supply chain management industry in the long run. There is no doubt that government mandates, incentives, and market development all together can speed up the diffusion of RFID in retailers.

To help these adoption activities, we present an RFID technology adoption analysis framework, taking into consideration the differences between retailers in China and those in other parts of the world. The proposed analysis framework can address the challenges faced by retailers in China to fulfill their needs for introducing new technologies. The framework is illustrated through an example of retailers in China to adopt RFID in their operations. In the illustration, we have constructed analysis processes taking input like technology development level, internal human resource, and external connections faced by retailers in China into analysis consideration to help the adoption analysis. The example shows the technology development level has a strong impact over the value perceived by retailers. For example, the RFID misread rate could easily smooth out any advantages by adopting RFID in inventory control in retailer RIC. This leads to a situation where adoption of RFID would not yield solid gain to the benefits of retailer RIC unless the RFID misread rate drops. The illustration has also demonstrated that RFID adoption shall come with right business process reengineering to transform the business operations in the retailer to benefit from RFID innovation. The illustration is based on the assumption that RFID value chain exists such that manufacturers, distribution centers and retailers can all source and deploy interoperable RFID and standards in their operating environment.

In summary, our analysis framework is open to any research methodologies. We take a system integration approach (SIA) in developing the value analysis framework for RFID technology adoption. The framework utilizes analysis processes to conduct the technology adoption analysis. This brings unique advantages to flexibly construct adoption analysis to entertain different analysis requirements. The framework is open to new technology analysis models and methods. Further, the framework provides interactive analysis capabilities which allows users to adjust input to each step in the analysis processes. And this analysis framework via service platform implementation can address the following challenges faced by retailers in China, as many of these retailers are not that resourceful to preserve enough business or IT skills to conduct extensive analysis in order to make decisions whether to adopt RFID in their operating environment.

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